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BIOLOGICAL RHYTHMS AND ROTATING SHIFT WORK

Some Considerations for Air Traffic Controllers and Managers

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| 16. Abstract This report is a general review of some of the current themes and practices regarding shift work; to inform controllers, technicians, and managers of these issues; and to offer some ideas that may be helpful in dealing with difficulties in this area. There is no pat or easy single solution to the problems of every employee. Managers are always faced with difficult decisions, and shift work is one of the most difficult because it can become an emotionally charged issue. (Key words: <i>circadian rhythms</i>) | | | |
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**Biological Rhythms and Rotating Shift Work:
Some Considerations for Air Traffic Controllers and Managers**

INTRODUCTION.

Rotating shift work and rapid travel across time zones has given rise to a relatively new set of physiological and psychological problems that have received considerable public exposure. The term "jet lag" has become a household expression; the Public Broadcasting Company put on a series called "The Brain" in which time sensitive nervous functions were explained. Congress has heard much testimony on the effects of rotating shift work on human health and industrial production. There is now active scientific research underway attempting to find ways to help people adapt quickly to these temporal dislocations. This is not a new subject for the FAA in that air traffic control specialists (hereinafter referred to as "controller," working in all three career options/facilities, i.e., centers, towers, and flight service stations) and managers have been dealing with rotating shift work since the inception of air traffic control over 50 years ago.

The purpose of this paper is to review in a general way some of the current themes and practices regarding shift work; to inform controllers, technicians, and managers of these issues; and to offer some ideas that may be helpful in dealing with difficulties in this area. There is no pat or easy single solution to the problems of every employee. Managers are always faced with difficult decisions, and shift work is one of the most difficult because it can become an emotionally charged issue.

BACKGROUND.

All FAA studies, and there have been many, regarding air traffic controllers' attitudes have shown them to like their jobs and to take pride in their work. However, because of the life-disrupting effects of inconsistent hours of work and rest, many controllers find rotating shift work disagreeable. Controllers are not alone in their opinion; thousands of pages of research data attest to the fact that other worker groups around the world share that view. Depending on one's source of information, the literature indicates that there are 14 - 25 million people in the United States alone whose work calls for them to rotate between day and night shifts. These people are involved in keeping the machinery of civilization running 24 hours a day; they are engaged in activities that range from public safety functions, such as police and firefighters, to medical personnel, members of the armed forces, and factory and service workers. One FAA bibliography of shift work lists over 1300 references to work done since 1950 and other bibliographies are almost as extensive. Granting that there are duplications in these lists, one is still struck with the mountainous quantity of information available on this broad subject.

There is a thread of consistency that runs throughout the literature on attitudes toward shift work. Firstly, workers generally consider work and off-duty time as an integrated concept; in order to obtain desired time off for discretionary use, workers will commonly accept long hours and/or arduous

work schedules. Secondly, most workers everywhere dislike the midshift (midnight to morning), prefer day or evening shifts, and desire a steady work schedule to any pattern of rotating shifts. Of these factors, there is the greatest commonality of opinion about the midshift. In fact, "shift" is almost a code word for midshift (day and evening assignments are accepted as normal, non-shift work hours). Among shift workers, practically all reported problems are related to the "graveyard shift" because of the physiological, psychological and social disruptions associated with it. For these reasons, FAA shift workers have a high level of interest in this issue.

Biological Time Clocks

Eating, sleeping, waking, and other regular activities are such common human experiences as to need no description. Such functions are usually thought of as being regulated by external or environmental factors; however, it is a well-established fact that these and, indeed, all bodily functions are coordinated and regulated by discrete groups of cells in the brain that comprise the so-called biological clocks. Because these internal clocks continue to run on their accustomed schedules, problems arise when a person's activities are displaced by several hours, such as a shift change or by rapid crossing of several time zones. Such people are said to suffer from desynchronosis, dyschrony, dysrhythmia, jet lag, or jet syndrome. The most prominent symptom is fatigue, but many also include indigestion, confusion, irritability, sluggish mentality, various aches and pains, insomnia or somnolence, constipation or diarrhea, and a general malaise.

These problems are rooted in the relationship of almost all living things (viruses and some bacteria possibly excepted) to the light/dark cycle attendant on the earth's rotation. The first recorded observation of such daily, diurnal or circadian (pronounced either circaDian or cirCadian) rhythms was made by a French astronomer, Jean de Mairan, in 1929, who noted that a heliotrope plant that opened its leaves at daylight and closed them at dusk continued that cycle of activity when kept in a dark closet. It was evident that the plant kept time by some internal mechanism. Thus, it has been known for over 250 years that living systems' regular activities are controlled by biological clocks.

In humans, the wake/sleep cycle and the internal body temperature cycle are synchronized, or phase related. Phase refers to the time reference on the circadian cycle. A phase shift means that the reference point is either advanced or delayed without changing the length of the cycle. When no time cues exist, as in artificial experimental environments, the wake/sleep and body temperature cycles lose their phase relationship or dissociate, a condition known as internal desynchronosis. Under these circumstances, the free running cycles also become extended to about 25 hours instead of the customary 24 hours. Because of this extension of the intrinsic biological day, the biological clocks must be reset each day of normal life to conform to the solar day.

For people who do day work and sleep at night, the body temperature swings through its low point between three and seven o'clock in the morning, with considerable individual variation. Alertness, which is related to body

temperature, is lowest at this time and people are then most prone to error and accidents. It has been shown, for example, that single vehicle truck accidents most commonly occur in the early morning hours. The body temperature high point occurs about 12 hours later, in the afternoon, and alertness is greatest at that time. This circadian swing in body temperature amounts to 1 to 2 degrees Fahrenheit.

When one changes from day to night work, about a week is required for the biological clocks to become readjusted to the new schedule, depending on how many hours are involved in the change. The clock controlling the wake/sleep cycle is located in the deep part of the brain called the hypothalamus. The brain cells controlling the temperature cycle have not yet been located but are known to exist and comprise a separate oscillator (clock).

Shift Work Rotation.

The observation that the intrinsic cycles are longer than the solar day has led to the recommendation that shifts should rotate in the same direction as the biological day; that is, workers should progress to later instead of earlier shifts. Rotations to later shifts are phase delayed and those that progress to earlier shifts are phase advanced. While the advantages/disadvantages of such rotation patterns are fairly subtle and may perhaps be overridden by environmental factors, it is claimed that adaptation to phase delayed schedules is easier than with phase advanced schedules just as east-to-west flight across several time zones produces fewer jet lag symptoms than does west-to-east flight. It has been estimated that a person can readily adapt to a span of about 3 hours of displacement without experiencing desynchronization. However, it is claimed that such acceptance occurs for only about 30 minutes of displacement for advanced schedules or eastward flight and 2.5 hours for delayed schedules or westward flight. There is not a great deal of data comparing delayed and advanced shift work schedules, but such experiments as have been done indicate, for whatever reasons, that phase-delayed rotations were characterized by increased productivity, improved worker health, and job satisfaction.

FAA SHIFT WORK SCHEDULE DESIGNS/PRACTICES

A variety of shift work plans in effect at ATC facilities range from straight shifts, that allow employees to work the same hours, sometimes of their choice; to rotation patterns, that may change rapidly (compressed) or slowly (expanded), and may be either phase delayed or advanced. On paper, one could design a number of shift rotation patterns, but not all of them would be practical or usable in the ATC setting.

Shift Work Models

The familiar 2-2-1 rotation preferred by many controllers, especially the younger ones, is an example of a phase advanced, compressed schedule. The long interval between work weeks (about 80 hours, or 48 percent of the 7-day week) is realized by compressing 40 hours of work into an 88-hour period. Obviously, such compression takes place at the expense of shortened intervals between work sessions (quick turnarounds).

TABLE 1

Compressed 2-2-1 and Expanded 1-2-2 Schedules

| (Phase Advanced) | | | | (Phase Delayed) | | | |
|------------------|----------------------------------|--------------|---------------|----------------------------------|--------------|---------------|--|
| Day | Work Hours (24-hour clock) | Off Hours | Total Week | Work Hours (24-hour clock) | Off Hours | Total Week | |
| 1 | 1600 - 2400 | 14 | | 0000 - 0800 | 22 | | |
| 2 | 1400 - 2200 | 10 | | 0600 - 1400 | 18 | | |
| 3 | 0800 - 1600 | 14 | | 0800 - 1600 | 22 | | |
| 4 | 0600 - 1400 | 10 | | 1400 - 2200 | 18 | | |
| 5 | 0000 - 0800 | | | 1600 - 2400 | | | |
| | 40 | 48 = | 88 | 40 | 80 = | 120 | |
| | | Off Duty = | 80 | | Off Duty = | 48 | |
| | | | 168 | | | 168 | |

If the 2-2-1 is reversed, it becomes a 1-2-2 expanded, phase-delayed schedule. Thus, the work week starts with a midshift, progresses through two day shifts and two evening shifts, ending at midnight on the fifth day. The result is an expanded work week with 40 hours of work spread over 120 hours. The off duty period between work weeks would be 48 hours and intervals between 8-hour work periods would range from 18 to 22 hours (slow turnarounds). As mentioned above, it is possible to devise compressed, phase-delayed schedules as well as expanded, phase-advanced schedules. However, all schedules call for 40 hours of work in five 8-hour days; the difference between them is in the distribution of time off. The importance of long weekends to workers everywhere is emphasized by the fact that the expanded 1-2-2 is not known to be in use in any industrial setting. Workers will accept almost any work schedule that will provide preferred time off. In the nuclear power industry, some plants operate on 12- and 16-hour shifts. Some law enforcement officers work 12-hour shifts for 4 days, then have 4 days off. One of the perquisites, "perks," of seniority or rank is the choice of work schedules, thus of time off. More and more often workers are bargaining for time off instead of monetary compensation. Swedish industrial workers now put in an average of 28.8 hours per week, the least in the industrial world; they would rather have leisure time than cash because of the high tax rate - "The more we make, the more they take". West German metal workers struck in 1984 for a 35-hour week; they won a 38.5-hour week, thus breaking the 40-hour barrier. Apparently, once cash compensation is adequate, it is not as powerful an issue as is time off for life enrichment activities that can be indulged with the cash. Table 1 compares the compressed, phase advanced 2-2-1 schedule with the expanded, phase delayed 1-2-2 schedule.

Another schedule in common use is the "straight five" pattern of shift rotation, meaning that employees work five days on the same watch, have 48 hours off, then change to another, usually earlier, shift. Some straight five patterns keep the controller on the day and evening watches for 2 weeks, followed by 1 week of midwatches. In most, if not all cases, phase advancing patterns of rotation are used. FAA research has shown, and other researchers agree, that 5 days is the wrong rotation frequency from the standpoint of circadian rhythmicity. Five straight midshifts lead to accumulated fatigue because of inadequate time to entrain circadian rhythms to night work and day sleep. Day sleep is almost always reported to be unsatisfactory with noise and light being blamed. However, circadian principles reveal that bedtime and wakeup time are related to particular places on the wake/sleep and temperature cycles. The problem with day sleep is that the unadapted worker tries to sleep when his/her biological rhythms are preparing him/her for waking activity. Thus, fatigue-induced sleep is brief and generally inadequate.

The 2-2-1 as presently worked is better than the straight five because four of the five watches are contained within the normal range of wakefulness. Most people sleep 6 to 7 hours per night and go to bed between 2200 and midnight. Except for the single midshift, the 2-2-1 provides essentially day work and night sleep and minimal circadian disruption. The single midshift is followed by an 80-hour weekend that provides abundant time for rest. Because traffic is characteristically light on the midshift, staffing is adjusted so that most crewmembers double back to day or evening shifts for the last workday of the week.

Reduced to the simplest terms, problems with rotating shifts and the attendant circadian disruption are almost exclusively connected with midshift work. Sleepiness is inevitable on the midshift, particularly during the period of circadian low, and is exacerbated by the work underload that is usual during the night. A demanding workload is arousing and, in many respects, is easier to deal with than is underload. Obviously, during periods of heavy traffic, ATC facilities adjust staffing to meet the need. This means that a variety of work is available, providing relief through duty changes. Also, social interactions are plentiful and breaks are readily provided.

Midshift Work

Two strategies are available for dealing with midshift work in towers, centers and TRACONS: (1) working the midshift long enough to become entrained to the schedule or (2) keeping midshift work to the minimum. Most controllers prefer the latter option and are probably wise in their choice. Arguments against the first option (prolonged midshift scheduling) are as follows:

(1) Circadian disruption occurs when the change back to day activity and night sleep is made on the weekend.

(2) Loss of proficiency by dealing with low traffic volume for long periods.

(3) Isolation from mainstream of facility activities.

- (4) Problems as crew briefings are given during the daytime.
- (5) Loss of training experience, both giving and receiving.
- (6) Reduced social contacts at work as well as away from work.
- (7) Disruption of normal family life.

Another variant is the work pattern used at the Miami International Flight Service Station (MIA IFSS). Day, evening, and midshifts are covered by people who work those periods without rotation. This pattern of work is popular at that facility because it affords regular, and sometimes preferred time off. This regular time off is of great importance to people who use it for farming, business, recreation, or whatever their lifestyle calls for. Measurements made at the MIA IFSS during a recent FAA study showed that there was significantly less subjective fatigue on the steady shift compared to the 2-2-1 rotation also worked at that facility. The amount of sleep obtained in connection with the two work patterns was not significantly different; the difference in subjective fatigue was probably related to better quality sleep associated with the steady shift than the 2-2-1. It must be remembered that the work distribution patterns at the MIA IFSS were customized to be consistent with operational needs at that facility. This same model might not work as well at a terminal or center facility.

The Miami study focused our thinking on some important aspects of shift work. While the importance of circadian effects is not disputed and we must always be mindful of them, we have come to realize that they are not all-important; that is, social, economic, industrial and environmental factors as well as personal preference are also important and can override circadian effects. Of these factors, personal preference or freedom of choice is of great importance because it means that a worker has more control over his/her life than might otherwise be the case. For this reason the FAA has established the practice of local option with input from controllers regarding shift work.

Performance Impairment, Health, Fatigue, and Shift Work

Many studies point to performance impairment associated with desynchronosis. As mentioned previously, when body temperature is lowest, error proneness is greatest. This would then translate to the midshift period between 3:00 a.m. and 7:00 a.m. as being a critical period. However, in actual practice, controllers errors do not occur in any greater number here. This can probably in part be explained by low traffic during midshifts. Short term memory is one function known to be adversely affected at the time of circadian low temperature, which can lead to human error. In some professions, such as air traffic control and medicine, however, error-free performance is the expected norm. There is evidence that such error-free performance, when attained by greater than ordinary effort, occurs at a commensurately greater physiological and psychological cost, sometimes called stress.

Fatigue is the commonest complaint associated with rotating shift work. When fatigue is not reversed by an off-duty rest period, it means that the worker returns to work in a tired condition. A week of consecutive midshifts, for example, might lead to accumulated fatigue that could affect the next week's performance on the day shift if the weekend does not provide complete recuperation.

It is not possible to make an unequivocal all-encompassing statement about the effects of rotating shifts on workers' health. Some studies in which large populations of industrial workers were examined have claimed that deaths from cardiovascular diseases were more common among shift workers than among straight day workers. An FAA air traffic controller health change study, conducted in the late 1970's, showed that controllers had a higher occurrence of high blood pressure than did comparable people in general population. However, there are so many factors (variables) involved in such studies that it is not possible to attribute the findings to one factor alone, such as rotating shift work or even to the work itself. The general statement can be made, though, that people experiencing desynchronization are temporarily in a state of internal disarray. Glandular secretion rates vary and become greatest or least at inappropriate times of day, thus rendering the person ill-equipped either to deal with crises or to go to sleep.

Considerations for FAA Managers in Designing Schedules

(1) Operational requirements and considerations must come first. The literature is clear that any shift work design must take into consideration the nature of the work, and the work itself may limit various scheduling options.

(2) Administration of shift schedules must be manageable and understandable by both management and controllers. Trying to accommodate too many needs may create confusion and dissatisfaction.

(3) To the extent practicable (consistent with operational requirements) employee desires and needs should be taken into consideration.

(4) Midshift duty should be minimized. The midshift is clearly the shift that causes the most circadian disruption. As such, the fewer midshifts worked, the better.

(5) Educate employees. Employees and supervisors should be aware of the circadian process. Desynchronization is mainly associated with the midshift; awareness of the circadian low temperature that occurs in the predawn hours is of prime importance to everyone.

Possible Employee Strategies for Coping with Shift Work

Dietary regimens have been proposed for reducing the effects of jet lag by speeding up the circadian adjustment process. There is evidence, primarily from animal experimentation, that certain food components act directly on the biological clocks. Travelers are advised to alternate light and heavy meals several days prior to flight, to fast during the flight and to eat breakfast

upon arrival at the destination. It is further recommended that travelers eat high protein breakfasts and high carbohydrate, low protein dinners to hasten entrainment to advancing schedules (eastward flight). Caffeine is a so-called chronobiotic substance; when used according to common sense can aid wakefulness, it can also speed the entrainment process. If these principles apply to air traffic controllers working a series of midshifts, and we are not saying this is the case, one would expect that (1) high protein meals before going to work; (2) high carbohydrate, low protein meals upon leaving work; and (3) together with caffeine in coffee or tea during the first half of the shift and abstinence the last half, would aid the entrainment process. For controllers working only one midshift, however, it is doubtful that dietary adjustments would accomplish very much.

In no case should stimulant drugs, such as amphetamines, be used on duty to enhance wakefulness, nor should sedatives be used for sleep induction. Dependency or addiction can develop, of course, but one should also be aware that drug effects can wear off at inappropriate times and leave one worse off than might be the case had drugs not been used. Further, proponents of dietary manipulation as a way of dealing with desynchronization, advise strict abstinence from alcohol during the entrainment process.

CONCLUSIONS

Circadian rhythm displacements as a consequence of air traffic control work are recognized and accepted by controllers as part of the job and are usually dealt with effectively on an individual basis.

The FAA's policies regarding shift work are fair, mature, flexible, and democratic. Controllers are well compensated for their work and are aware of the necessity for working unusual hours. Night work is distributed fairly by rotation practices. Workers have considerable input into present shift work practices, allowing maximum flexibility in conduct of their lives. No safety problems in ATC are known to be related exclusively to circadian effects; no medical problems are known to result from rotating shift work.

Though the negative aspects of shift work are usually emphasized, there are also positive features, such as premium night differential pay and daytime hours for other pursuits.

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